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40TH ANNUAL CONVENTION
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Professor K. P. Young, President of the Club, third from the top, nearest row,
Professor H. C. Chang, Vice President, fifth from the top, same row, and

SIGMA XI QUARTERLY

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THE SIGMA XI CLUB OF PEKING, CHINA

The picture on the opposite page is impressive evidence of the far reaches of the Sigma Xi membership and purpose. The Sigma Xi Club of Peking, China, was organized in 1931 at Yeuching University in Peiping, China, and has held several meetings each year since its founding. Professor Stanley D. Wilson, Dean of the College of Natural Sciences at that University, whose interest in science and enthusiasm for our great society proved contagious and led to the organization of the club, was elected a member of Sigma Xi by the Chicago Chapter in 1913 because of his brilliant work in the field of chemistry. At the annual meeting of the club last May, an address, "The Study of Tuberculosis," was given by Dr. Eugene L. Opie of the Cornell University Medical College who was visiting professor at the Peiping Union Medical College.

THE 40TH ANNUAL CONVENTION

The 40th annual Convention of the Society of the Sigma Xi is scheduled to be held in Columbus, Ohio, December 28 next. Among the important items of business which the Convention will be called upon to consider are the following:

a. Petitions for charters for chapters from the University of Southern California and the Virginia Polytechnic Institute.

   These printed petitions will be distributed to the chapters November 1.

b. Reports of Committees on the QUARTERLY and the Membership Structure.

c. Reports of the President, the Secretary and the Treasurer.

d. Election of a President, a Secretary and a Treasurer for the ensuing biennium, and of a member of the Executive Committee and of the Alumni Committee for a five-year term.

   The Nominating Committee is composed of President Karl Compton, Massachusetts Institute of Technology, Chairman, Professor P. H. Mitchell, Brown University, and Dean F. K. Richtmyer, Cornell University.

   Chapters may make suggestions to the Committee direct, or through the National Secretary.

e. The 18th annual Sigma Xi lecture will be given by Professor Kirtley F. Mather on "The Future Man as an Inhabitant of the Earth."

SIGMA XI GRANTS-IN-AID FOR 1939-40

The Committee on Sigma Xi grants-in-aid met in the Faculty Club, Cambridge, Massachusetts, July 24. Present were Doctor Whitney, Professor Shapley and Professor Calkins, members of the Committee; President Baitsell and Secretary Ellery; and by invitation, Dean Richtmyer.

Grants were voted as follows:

1. JOHN B. BUCK, Research Assistant, Department of Embryology, Carnegie Institute of Washington, Baltimore, Maryland. *Project:* Studies on the methods of light-production in the firefly. ($100.)
2. MAX DEMOREST, Assistant Professor of Geology, University of North Dakota, Grand Forks, North Dakota. *Project:* Studies of the "petrofabrics" of ice and the development of an instrument suitable for these studies. ($150.)
3. GEORGE Z. DEMITROFF, Oak Ridge Station, Harvard Observatory, Harvard, Massachusetts. *Project:* Completion of instrument for photo-electric photometry of faint stars. ($250, on condition that $100 will be contributed from another source.)
4. GEORGE W. KIDDER, Assistant Professor of Biology, Brown University, Providence, Rhode Island. *Project:* Continuation of study of growth substances produced by Ciliate populations. ($200, renewal.)
5. WALTER DANDAUER, Head, Department of Genetics, Storrs Agricultural Experiment Station, Storrs, Connecticut. *Project:* Study of various genetic and developmental problems on skeletal traits. ($350, on condition that the institution provide an additional sum of $90.)
6. REGINALD D. MANWELL, Professor of Zoology, Syracuse University, Syracuse, New York. *Project:* Immunity in avian malaria. ($200.)
7. DUNCAN McCONNELL, Instructor in Mineralogy, University of Texas, Austin, Texas. *Project:* Continuation of structural investigations of phosphate minerals. ($150.)
8. ELMER RAY NOBLE, Assistant Professor of Biology, Santa Barbara State College. *Project:* Host-parasite relationships, with particular reference to myxosporidia and other protozoa. ($100.)
9. FRANKLIN E. ROACH, Assistant Professor of Physics and Astronomy, Assistant Astronomer, Steward Observatory, University of Arizona, Tucson, Arizona. *Project:* Study of eclipsing Binary stars. ($200.)
10. BENJAMIN G. P. SHAFIROFF, Instructor in Surgery, New York University College of Medicine; Assistant Attending Surgeon, Bellevue Hospital, New York, N. Y. *Project:* Absorption of bile by the lymphatics of the liver whose common duct is obstructed under various degrees of pressure. ($100.)
11. ROGER M. REINECKE, Senior in Medical School, University of Minnesota, *Project:* Certain effects of previous diets. Metabolism of fructose hypophysectomized rats. ($180.)
12. C. DONNELL TURNER, Assistant Professor of Zoology, Northwestern University. *Project:* Continuation of work in endocrine physiology. ($200.)

SOME CONTRIBUTIONS TO THE GEOLOGIC SCIENCE BY ECONOMIC GEOLOGISTS

C. F. Tolman
Stanford University

I accepted with great pleasure the invitation to address this Society. It was suggested that I follow the custom of the Society and present the results of the research on which I am engaged. Further consideration suggested that the Society might be interested in the contributions to the geologic sciences by present day economic geologists, and so I have selected as the subject of this talk "Some Contributions to the Geologic Sciences by Economic Geologists." I introduced the adjective "some" to give me freedom as to what advances and contributions I might discuss to support my contention that the detailed studies of economic geologists of recent years are furnishing us a real foundation on which to build a worthwhile science of geology.

On starting preparation of the paper I found myself confronted with the inability to devise a satisfactory definition of economic geology in spite of the fact that I have taught the subject for over thirty years and practised it for nearly forty years. I looked up the definitions in various textbooks of economic geology and public addresses by scientists on the subject and found none that satisfied me.

A definition by R. A. F. Penrose, Jr., is: "The term Economic Geology is used to indicate the application of the general principles of purely Philosophical and Theoretical Geology to material use." I do not know what "purely Philosophical Geology" is, and I hope that it does not refer to the age of scientific ignorance dominated by the philosophers who stated half truths in their syllogisms rather than reasoning from established facts. Also the term theoretical geology has an unfortunate reaction on the man in industry, and for many years the theoretical scientists were considered to be impractical scientists and their theories of no value to the workaday world.

Brooks defines applied geology as the "science which utilizes the methods and principles of pure geology to supply the material needs of man." Here again I have difficulty in distinguishing between "pure" and "impure" geology. If the impure geologist is one who accepts money to carry on his research, I am afraid we all are more or less impure. If our work was always successful in supplying the material needs of man there would be no need of relief for the geologists.

S. F. Emmons realized the difficulty in separating applied geology from the geologic sciences and offered the definition that pure geology is not yet applied geology, a definition which unduly limits the realm of pure geology.

Although I hesitate to define economic geology I can state, however, that present day practice of economic geology now consists largely of the application of all methods of geological research to the detailed investigation of some particular problem of economic import.

The geologic sciences are far behind the other physical sciences in developing fundamental principles and controlling laws because few of their problems can be taken into the laboratory for experimental study, and the art of geology consists of making fragmentary observation at ground surface and the projection of these observations to unseen and unknown depths below ground surface. Hence the very nature of the geologist's work fosters the practice of drawing conclusions on insufficient supporting data.

The debt of applied geology to the geologic and physical sciences is, of course, recognized by all investigators. Without the collection and analysis of geologic data which is the foundation of the geologic sciences we could do no work in applied geology. For example, the study of ore deposits, perhaps the most advanced of all the branches of applied geology, owes much to mineralogy, to the experimental work of geophysicists and geochemists who have determined the stability ranges of various minerals and established a geologic thermometer by which the temperature of ore formation can be determined, to petrography which has studied not only the unaltered rocks which bear the ore deposits but also rock alterations accompanying ore deposits, and the results of this study and of chemical analyses of fresh and of altered rocks has given us some notion of the chemical composition of intruding solution which deposited the ore.

Merrill has divided the development of the geological sciences in America into the following periods, namely, one, *a period of speculation;* two, *the period of observation;* and three, *the period of verification.* The *period of speculation* dates back prior to the organization of State Geological Surveys which culminated in the establishment of the United States Geological Survey. It was a period of speculation with meager and, in some cases, without any foundation of observed data. Unfortunately, the period of uncontrolled speculation did not entirely cease with the development of the geological surveys and the collection of observed data. Although present day speculators attempt to use data furnished by all the physical sciences, they do not hesitate to reason by analogy and draw conclusions as to happenings in realms entirely beyond observation by man.

I would subdivide Merrill's period of observation into a period of *general observation* and a final period of *detailed observation,* omitting his period of verification for every sound observer has and will correlate his work with that of other observers. The period of general observation is further subdivided; the scheme here adopted is as follows:

I. Period of Uncontrolled Speculation—from the beginning of history to 1830, the start of State Geological Surveys.
II. Period of General Observation:
    A. The Epoch of State Surveys—1830 to 1860.
    B. The Epoch of United States Exploratory Surveys—1865-1880.
    C. The Epoch of United States Geological Survey's dominance, 1880 to the World War—1914.
III. Period of Detailed Observation—1914-1938—World War to date.

The Period of General Observation started with the organization of state surveys commissioned to examine the natural resources of the states. The year 1833 registered the largest percentage of State Geological Surveys until the

year 1898. The Epoch of the Exploratory Surveys was the response of geology to the development of the Great West. Demand for information as to the economic possibilities of this region was high. Gold had been discovered in California, and the various explorations carried on by the government were of the highest class of reconnaissance geology. They give us an accurate description of outcrops which record the geological story with a clearness and legibility that astonished the Wise Men from the East, and on these observations many of the broad principles of geology were founded.

To be classed with these is Whitney's Geologic Survey of California, and as an example of the danger of applying geological generalizations to detailed economic problems I will recall that Whitney stated that if oil was to be found in commercial quantities it would not be in southern California where rocks were broken and faulted and where the petroleum products had escaped, but would be found in northern California where the rocks were more gently folded and the liquid hydrocarbons would be retained at depth.

The Epoch of the Domination of the United States Geological Survey over geologic thought in America registers the greatest advance in the geological sciences. The work of the survey was both economic and general, and all of the branches of geology received treatment; and from the contributions of the members of the Survey the principal advances in all of the geological sciences were made possible. Some might consider that Emmons' classical study of Leadville, that Lindgren and Ransome's many monographs, that Van Hise and his associates' work in the iron ranger of Minnesota and Wisconsin might be considered detailed geological work, but according to the practice of present day economic geologists these still are of reconnaissance character.

The Period of Detailed Observation marks the decline of the United States Geological Survey in directing geologic thought and may be considered as starting the Great War. The period of general geologic observations and cursory examinations of our mineral resources is past. The young economic geologist often spends as many days on a square mile as the older geologist did on a thousand square miles. The geologic cross-sections drawn from cursory examinations of a few outcrops and exposures miles apart and observed dips perhaps even further apart have given place to detailed cross-sections. A few years ago the mining geologist at Bisbee spent some three months in making a type cross-section. He measured the section well exposed in cliffs by a foot rule, subdividing the great limestone members in some cases to horizons a few inches thick. This geologic cross-section was used a key section with which the underground maps were correlated and checked.

The adjective economic can be used to modify all branches of geology, such as economic paleontology, economic structural geology, economic mineralogy, etc. Examples discussed in this address will include economic paleontology, ore deposits and foundation geology. It is hoped that these illustrations will be sufficient to show the detailed character of the work now required of economic geologists and also some pitfalls that await the geologist who does not also understand the practical nature of the problems he is investigating.

Descriptive paleontology, especially of microfauna, has grown by leaps and bounds since laboratories were established by the oil companies for the pur-

pose of studying the fauna as an aid to the working out of the stratigraphy of the oil fields. There are probably over one hundred well equipped micropaleontologic laboratories in this country. The Foraminifera have been described by these workers in more detail than any other great order of organisms. The stratigraphy and the compilation of the geological column in the oil fields has been worked out in greater detail than would have been possible for investigators without the facilities given the geologist by the operating companies.

Ralph Reed's book, "The Geology of California," is a compilation chiefly of the detailed work of the oil geologists and paleontologists because most of the detailed work in California geology has been done by them. This work was financed by the Texas Oil Company and was published by the American Association of Petroleum Geologists. It shows the attitude of the economic geologist in that he rarely answers the problems brought up by detailed study but merely states them.

A notable work financed by the Shell Company is that of Manley L. Natland, entitled, "The Temperature and Depth Distribution of Some Recent Foraminifera in the Southern California Region." Mr. Natland studied the wonderful Pliocene section exposed in the Ventura anticline. Here 15,000 feet of Pliocene sediments are exposed in the canyons eroded in that structure. He compared the microfauna of these strata with that of the deeps on either side of Catalina Island and divided the present day marine fauna in zones based on temperature and depth of water. In comparison with the geological section through the Ventura anticline, he found that the uppermost strata of the Pliocene presented numerous faunal markers, characteristic of the shallow, brackish water zone. Then downward in the section the faunas in the exposed strata were correlated with the faunas shown at increasing depths under the ocean. The base of the Pliocene formations contain typical present day fauna living at depths of 6,500 feet to over 8,000 feet with bottom temperatures ranging from 4° C. to $2\frac{4}{10}$° C. Mr. Reed stated facetiously that a sample at greater depths would represent a fossil fauna of Miocene age. The result of these investigations must be borne in mind in the discussion of the sediments deposited in the extraordinarily deep trough and fault blocks in California and also bear on the problem of environment versus geological age in stratigraphic classification.

Prior to the great development of the oil industry the group of economic geologists studying ore deposits outnumbered those in any other line of geological work. Also speculation in regard to the deposition of the precious and base metals has been practised since early times. Hence, attention is directed to a very brief review of a change of attitude from speculation founded on fancy to classification founded on observed facts.

In Europe prior to the Great Renaissance and development of the scientific attitude, the geological speculations of the philosophers were directed largely to the origin of springs and of ore deposits, and because the structure and appearance of ores indicated clearly some of the agencies that formed them, some of the notions propounded have been substantiated, in part at least, by later observations. However, in the long list of speculations, one contribution stands out, and that is by Dr. George Baer (1494 to 1555), a German, who wrote under the nom-de-plume, "Agricola." It will be remembered that this

monumental work in medieval Latin has been translated and published by Mr. and Mrs. Herbert Hoover, and it is, indeed, one of the most interesting bits of reading available on mining and the mining people of that day. Baer described clearly the structure of the veins and while not stating any definite theory as to the origin indicates that some "lapifying juices ascended through the cracks and deposited the ores and altered the adjacent country rock."

The next outstanding names in the development of the theory of ore deposits are those of Werner and Hutton, and they founded the controversial schools of Neptunists and Plutonists. Werner's principal contribution was in 1791, Hutton's, 1795 and 1802. Werner, of course, taught that fissures were due to contraction of the earth's crust and were filled with material held in suspension and in solution from above, and that the ores were derived from a primeval ocean that once covered the earth. Hutton postulated ascending solutions from volcanic sources. Werner apparently was a forceful teacher, and in that day of authority which so hampered scientific research his theories in a modified form controlled geological thought. The struggle between these men and the contention they aroused is a classic example of the harm that was done by imposing one's opinions on others and telling them what must be believed.

In the middle of the nineteenth century principles of chemistry and physics had been developed. Experimental work was made on rock fracture; mineral synthesis was started and some of the general principles of geology stated. However, in respect to ore deposits the era of speculation dragged on and the struggle between rival authorities continued.

F. Sandburger, a modified Neptunist, in 1873 announced this theory of lateral secretions, founded on analyses of wall rocks of many veins which disclosed metals in the altered wall rock and postulated that the metals were leached from the metal-bearing rock and deposited in veins by descending solution; and he was combated by Posepny, the great mining geologist and progressive Plutonist, whose descriptions of Bohemian ore deposits are still classic. The parties changed names, and the Plutonist became the Ascensionist and the Neptunist became the Descensionist, referring, of course, to the origin and direction of movement of ore solutions. This controversy was imported into the United States and carried on by Van Hise on one side and S. F. Emmons and Kemp on the other, but the fact finding era had been well established in America; and the period from about 1890 to 1914 (the Great War) dominated by the United States Geological Survey has seen the analysis of facts observed during field study of ores take precedence over all theories handed down from the past, and from now on the science of ore deposits has been built on observed geological data.

The great monographs on "Lake Superior Copper Deposits" by Pumpelly, on "Lead Deposits in the Mississippi Valley" by Chamberlin, on the "Comstock Lode" by Becker, on "Leadville" by Emmons, furnished the fundamental data for the classification of ore deposits. All phases of geology contributed to our knowledge of ores. A study of topography showed the depth at which the ores were originally deposited. For example, Ransome and Lindgren reconstructed the Cripple Creek volcanic cone and the depth of ore deposits below this surface was determined. Also old topographic surfaces were studied, and their relation to the processes of secondary enrichment were determined.

Temperature at which ore deposits were formed was deduced from experimental work in geophysical laboratories on characteristic minerals, and these data were applied by studying the groups of minerals with which the key minerals are associated. The relation of ore deposits to igneous rocks and to contact metamorphism and the groups of ores formed at high, intermediate and moderate temperatures were studied, and the relation of ore families to igneous rocks and intrusive processes determined. Petrography furnished the method of studying the rock alteration along veins, and with the assistance of chemistry the probable composition of the solution causing these rock alterations have been determined.

Since the Great War the greatest advances in ore deposits is due to the development of special detailed method of underground mapping in mines. In general this is called the Anaconda method of geological mapping. Every fracture, every fissure, every rock alteration and type of ore are plotted on maps of the mine workings. So detailed is the mapping that the thickness and importance of the fissure is shown by the thickness of the pencil lines, and the mapper has pencils sharpened to a razor edge. The fundamental data thus collected now furnishes material that can be analyzed by the structural geologist. In some cases the types of fractures representing tensional stresses can be determined, and the fracture pattern can be analyzed along similar principles used by the dam engineer in studying fractures due to failure in a concrete structure.

The most important contribution of this type is the paper on Reno Sales on the copper deposits of Butte, Montana, and the detail shown in his illustrative cross-sections can only be fully appreciated if we remember that every line drawn on the mine maps represent some observed feature. An interesting sidelight on this great work and an example of the difficulty under which the economic geologist labors is that Mr. Sales has encountered difficulties in every subsequent law suit in which he has testified. In every case opposing attorneys study his work in greatest detail and attempt to bolster up their claims from data appearing in Sales' report, as a lawyer remarked to me: "Oh, that my enemy has written a book!" As a result of this unfortunate experience Sales has not permitted members of his geological staff to write any scientific publication. Those who were with him and have written have done their writing since leaving the Anaconda Copper Mining Company.

Very recently Mr. Sales was asked in a law suit if he had written a paper dealing with the importance of detailed underground mapping, and a cross-examining attorney quoted from Sales' own work to show that detailed underground mapping was of more value than the opinion of an expert based on a few days' work. In this case Sales spent only a few days at the mine while the opposite side made extremely detailed studies and constructed geological maps based on observing the working faces as were driven at least twice a day.

In my opinion, Mr. Sales' description of the Butte ore deposits is the most important contribution to economic geology written to date. A possible rival to this paper is one by M. B. Kildale who has written a Ph.D. thesis entitled "Structure and Ore Deposits of Tintic, Utah." It is hoped that this paper including his maps and geological cross-sections may be published shortly. Mr. Kildale's thesis is based on some ten years' detailed underground mapping in that district. His cross-sections are detailed pictures of the extraordinary

deformation the region has suffered, and his analysis of these conditions solves many problems in regard to the location of the ore bodies and the possible vents or ore "inlets" through which the ore solutions were introduced into the rocks of the Tintic district.

Foundation geology is now a well established branch of economic geology. The demand for foundation geologists has increased enormously in California since the failure of the St. Francis Dam due to the erroneous conclusions of an amateur geologist and also because the earthquake hazard must be evaluated if the engineer is to design and build safe structures. The engineers have welcomed the cooperation of the geologist because the geologist has taken a great responsibility from the shoulders of the engineers who demand an answer to the difficult question, "When is a California fault a dead fault or an active fault?"

One difficulty encountered by the foundation geologist is that his conclusions will be checked up when the foundation excavations are made. This is true, perhaps to a lesser extent, in all branches of applied geology and makes the economic geologist more conservative than the theoretical geologist whose speculations may never be subject to demonstration which will prove them to be either true or false.

Finally, ground water hydrology, largely a combined geological and engineering study, has become one of the important specialized fields of economic geology. As an example of the contributions of ground water students to geology I mention the extraordinarily detailed work of the ground water geologist in the Hawaiian Islands. The windward side of these islands has an abundance of water, from 300 to over 500 inches per year, and the leeward side has as little as 15 inches per year in places. On the dry side are the plantations; on the wet side is the water supply. The volcanic rock of the islands is the most pervious known rock formation. The water seeps downward through the rocks and forms an egg-shaped body of fresh ground water floating in a body of salt ground water. This basal body of fresh ground water is exploited only in areas, where the elevation is above sea level 500 feet or less. Valuable bodies of water have been found dammed between the dikes of the dike complex which constitutes the core of the Hawaiian mountain ranges. The dikes are of the same type of rock as the lava flows and are often exactly similar in appearance and cannot be distinguished by petrographic studies. However, the ground water geologist has learned to recognize minute structural criteria for separating the dikes and the flows and has mapped in the greatest detail the complex of dikes that form the core of the volcanic mountains of the Hawaiian Islands. These vertical water bodies enclosed by the dikes have been developed by long tunnels driven to intersect the dike complex in the center of the ranges. This detailed mapping of the ground water geologist has furnished us pictures of the structure of the Hawaiian volcanoes which could not be obtained by any other method of investigation.

In this address my attempt has been to show that the economic geologist is now carrying out investigations as detailed as the studies that have resulted in the discoveries of the other physical sciences, chemistry, physics and biology, and that he is worthy of being included in the roster of the Sigma Xi.

CLIMATE AND HOUSING

FRANK B. ROWLEY
University of Minnesota

The physical existence of man requires food, water, air, clothing, and shelter. On most parts of the earth nature provides for food, water, and air. In many parts clothing as we know it may be practically dispensed with, but it would be very difficult to find a place where man could exist with complete exposure to all elements of the climate. Climate has completely circumscribed the area in which many forms of animal life may exist and without some sort of protection or shelter the various climatic elements would restrict to an even greater extent the territories in which man could survive. Since man has not been content to confine his activities to those territories in which the climate is most favorable to his existence, shelter has been a prime requirement, and it has often taxed his intelligence to protect himself against the elements of the severe climate which he has chosen.

The human body is so constituted that it can stand exposure to rather wide ranges of most of the elements, but when we think of temperature ranges from 50° below zero to 110° above zero, or wind velocities from zero to 100 miles per hour all in the same locality, and the intense heat of the equatorial sun as compared with the weeks of no sunshine at the North Pole, or the torrential floods in some areas as compared with desert areas in which it never rains, and realize that man exists under all of these conditions by virtue of shelters which he has constructed we realize the importance of housing and its relation to climate.

A house often becomes a man's most prized worldly possession. It becomes an expression of his culture and art. It often represents the greater part of his worldly accumulations, and is the greatest monument that he leaves behind him. A house cannot be considered separate from climate as it has been the result of certain climatic conditions.

The elements which we usually group together and call climate are temperature, moisture, wind, and sunshine. We rate these various elements in terms of our comfort; thus when we say that it is hot or cold, wet or dry, windy or quiet, we refer to our own state of comfort and well being. Man has learned from experience that certain climatic conditions are best adapted to his comfort and health, and since the desired combination of conditions is seldom found in nature he must build a house and establish within that house the climatic conditions required. The elements of the climate which may be established within a house to suit a man's comfort and health have recently been given a great deal of study and are often referred to under the heading of air conditioning. Those elements of the inner climate which seem to be of the greatest importance in so far as the construction of a house is concerned are air temperature, moisture, and air movement.

This is not a discussion on air conditioning, but since many of the elements which vitally effect human comfort also place many restrictions on building construction, a brief description of their relation to the human system may be desirable.

The human system is particularly sensitive to air temperature, air movement, moisture, and sunshine. These elements all have a direct bearing on a man's feeling of warmth or coolness and are in the main the elements of the climate which we consider in constructing a house.

In so far as its heat reactions are concerned the human body may be considered equivalent to a heat engine. The hydrocarbons are oxidized by a process equivalent to combustion; heat is generated and part of it is converted into mechanical energy and the remainder must be given off from the body by the processes of convection, radiation, and the evaporation of moisture. In carrying out these various processes, air is taken into the lungs from where the oxygen is absorbed through the thin tissues of the lung into the red corpuscles of the blood. The oxygen is then carried to the various parts of the body where it unites with the hydrocarbons of the tissues by a process known as metabolism. Carbon dioxide and water are formed and heat is generated just as it is in the combustion which takes place in an ordinary furnace. The carbon dioxide is readsorbed by the red corpuscles of the blood and carried back to the lungs where it is exchanged for new oxygen, and the cycle repeated. The air we breathe thus serves to supply oxygen and to carry away carbon dioxide, together with some water vapor and heat. The greater part of the heat, however, is carried away by three processes, namely, radiation to the surrounding objects, convection to the air currents coming in contact with the body, and by the evaporation of moisture from the surface of the body. The total amount of heat generated by the average individual depends upon his state of activity. The average person seated or at rest generates 384 B. t. u. per hour or slightly more than the amount of heat from one 100-watt electric light. If walking at two miles per hour the heat generated is slightly greater than that from two 100-watt electric lights. When walking at three miles per hour it is slightly more than that from three 100-watt lights, and it increases up to the equivalent of fourteen 100-watt electric lights for maximum activity. There must be a balance between the heat generated within the body and that carried away by the different methods. Conditions are comfortable when this balance can be maintained without undue bodily adjustment.

The relative percentages of heat taken care of by each radiation, convection, and evaporation depends upon the amount generated, the construction of the building, and the air conditions maintained within the building. Under ordinary conditions within a house the temperature of the surrounding objects with the exception of outside walls are substantially the same as that of the air. The ouside wall temperatures may be warmer or colder than the air, depending upon outside weather conditions and the type of wall construction used. Thus in cold winter weather the average or mean radiant temperature of all of the surrounding objects including outside walls may be two or three degrees lower than air temperatures, thus increasing the amount of radiant heat that will be given off. The amount of water vapor in the air, usually expressed as relative hu-

midity, affects the ease with which moisture may be evaporated from the surface of the body and, therefore, affects the comfortable air temperature. Thus very dry air will feel cooler than very moist air. The optimum amount of moisture which should be carried for comfort or health has never been determined, but it is usually considered to be between 30 and 60 percent.

Under average conditions we have learned that an air temperature of about 70° F. is comfortable. This temperature is comfortable because its effect in combination with normal wall temperature, air movement, and moisture content is such that the heat generated in the body can be taken care of by normal processes without discomfort. If the temperatures of the surrounding walls were very much higher or very much lower than that of the air, then it would be necessary to either lower or raise the temperature of the air to give equal comfort, and we might be perfectly comfortable in air of either 50 or 90 degrees temperature if the other atmospheric conditions together with surrounding wall temperatures were such as to give a heat balance in the body. In other words, we are establishing within a house a combination or conditions under which the body may function normally and in which we may enjoy comfort and health.

A satisfactory house must be built to withstand all of the elements of the outer climate and make it possible to maintain the desirable elements for the inner climate without undue operating expense. This requires mechanical strength and the resistance to the passage of heat, moisture, and air.

One of the prime requirements of a building is strength. Its physical properties must be such that it will stand up against and resist the devastating effects of the most severe of the elements. A failure in the physical structure of a building is usually more disastrous and pronounced than a failure in any of its other properties. This quality has, therefore, received attention from the beginning of building construction, and today the home builder is fortified by a long line of experience and an available supply of design data. In addition to these he is usually protected by laws which regulate the minimum strength which may be built into a structure.

Resistance of a structure to heat and moisture have not been so readily apparent as some of its other properties and have, therefore, not usually received attention in the earlier or primitive forms of construction. It is only during the past twenty years that heat insulation has been given any great attention in the construction of houses, and only within the last three or four years has the moisture and condensation problem in a house been given serious thought. It is the resistance of the structure to these two climatic elements, heat and moisture, that will be chiefly considered in the remainder of this discussion.

THE INSULATION PROBLEM

Since the artificial, comfortable climate which we wish to establish within our houses may have a far different temperature than that of the normal climate of the location in which we build, the resistance to heat flow through a structure may have a very important bearing on the economic maintenance of the inside air conditions. All materials used in building construction have some resistance to the flow of heat. Unfortunately, however, those materials which have the

greatest structural value are of a nature which have but little insulating value and it is usually desirable to supplement these materials with others which have been designed specifically for their insulating qualities.

A long line of insulating materials have been developed in recent years for specific applications to different types of buildings. In general they may be divided into four classes; namely, rigid or board insulation, flexible or quilt insulation, fill insulation, and reflective insulation. Each has its advantage and no one is adapted to all types of construction. Rigid board insulation, as the name implies, has structural value and is often used as a substitute for wood sheathing or as a plaster base for the interior surface of the walls. It is also often used as an interior finish without plaster. The flexible or quilt insulation should be applied in such manner that it will retain its original thickness and not be compressed between other materials. It is often sealed midway in an air space to gain the effect of a second air space in addition to the material. In these applications the insulating material should be sealed at top and bottom to prevent the circulation of air around the insulation between the air spaces on the hot and cold side of the material. If not properly sealed the circulation of air may destroy a large percentage of the insulating value gained by this method of application. It is often easier in building a frame house to nail the flexible insulation on the outside of the studs underneath the sheathing. This reduces the insulating value obtained by placing the material between the studs for two reasons. First, no additional air space is gained and, second, the thickness of the quilt or insulating pad is materially reduced at the edges. As an illustration an ordinary frame wall with a ½-inch blanket of insulation nailed on the studs under the sheathing will transmit 12 percent more heat than the same wall with the same insulation well flanged between the studs. On the other hand, if the insulation between the studs is not sealed at the top and bottom of the space the wall will transmit approximately 33⅓ percent more heat than would the same wall with the insulation properly sealed at top and bottom.

Fill insulation, as the name implies, is usually applied in air spaces which are formed in walls. The air spaces may be those due to normal methods of construction, or the construction may be designed specifically to provide air spaces for the insulation. Its value depends upon the thickness applied and the type of construction. If an air space is completely filled with such a material the insulating value of the original air space will be lost, but it is probable, that the value of the material will be much greater than that of the initial air space. As will be explained later, the reflective insulating materials owe their insulating value to the fact that their surfaces have a high resistance to the passage of radiant heat and they must, therefore, be applied with their surfaces exposed either to an air space or to the exterior of a wall (Figure 1).

In many cases insulating materials within a wall do not cover the full wall area. They are placed in spaces or voids which have been allowed for structural purposes. In these applications the final results will depend not only on the conductivity of the material but also upon the conductivity of other uninsulated parts of the wall which may tie the exterior surfaces together and

provide paths for the heat to flow around the insulation. A good illustration of this principle is to be found in a comparison of the results obtained by the application of fill insulation between the studs of wood and metal framed walls. The insulating material may cover 90 percent of the area of the wall. If the remaining area is covered by the wood studs the application is effective as the studs themselves are reasonably low conductors of heat. If, on the other hand, the steel surfaces of a wall are tied together with steel connecting bars or studs these will form such good conductors that the insulating value of the material is practically lost. A similar condition may exist when fill insulating materials are used between two concrete slabs which are tied together with metal tie bars (Figure 2). The heat from the warm surface of the wall is readily con-

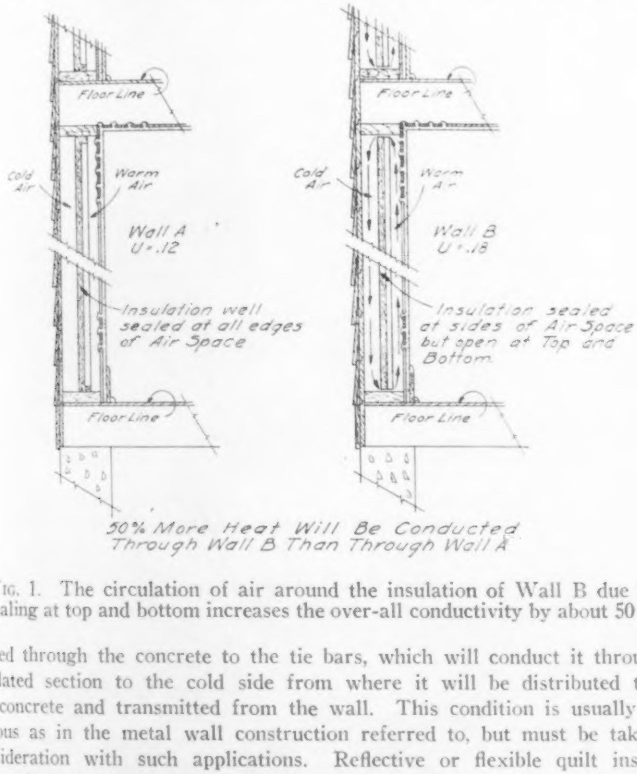

FIG. 1. The circulation of air around the insulation of Wall B due to lack of sealing at top and bottom increases the over-all conductivity by about 50 pecent.

ducted through the concrete to the tie bars, which will conduct it through the insulated section to the cold side from where it will be distributed through the concrete and transmitted from the wall. This condition is usually not as serious as in the metal wall construction referred to, but must be taken into consideration with such applications. Reflective or flexible quilt insulation, when placed in air spaces, are subject to the same criticism when these air spaces are divided by high conductivity materials. In any case when a material is used to build up parallel air spaces and depends upon these air spaces for its insulating value, the air spaces must be properly sealed to prevent the interchange of air between those on the hot and cold side of the wall. Effective insulation must take into account the transfer of heat through the wall by all

methods and through all parts of the wall. Each type of insulating material has its place in building construction and it is a mistake to consider any single material to be equal to all requirements.

AIR SPACES AS INSULATORS

Many materials owe their insulating value almost entirely to the minute air cells in their structure and larger air spaces are often an important factor in resisting the heat flow through a structure, but usually when we are thinking

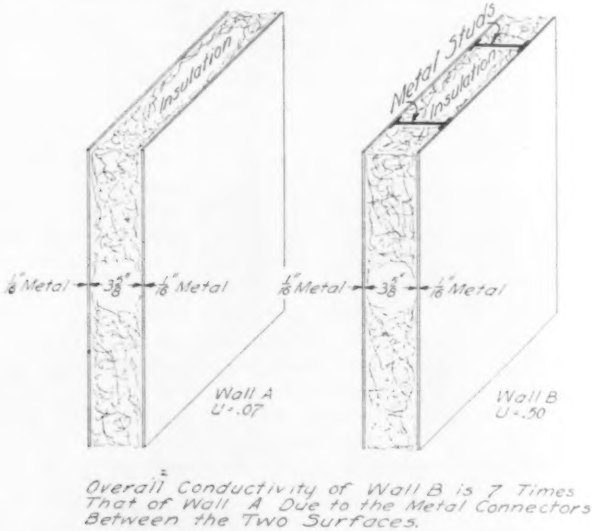

FIG. 2. The high conductivity for Wall B as compared with Wall A is due to the metal studs which give paths of high conductivity materials through the insulation.

of air spaces we are considering those large open spaces which exist in the wall, such as the open spaces in a tile wall, the core spaces of a concrete block, or the space between the studs of an ordinary frame wall, and we are apt to overrate their insulating value. Such air spaces are often spoken of as dead-air spaces, implying that the air is stagnant and still, and since the thermal conductivity of still air is low the air space is assumed to have a low thermal conductivity, or a high resistance to the passage of heat. This assumption is far from the conditions that exist. In the first place the air is not quiescent and still, and in the second place a large percentage of the heat in an ordinary air space is transmitted across by radiation and not by convection or the circulation of air. For an ordinary air space one inch or more in width lined on the surfaces with such materials as wood, paper, brick, etc., about 60 percent of the heat is transferred from one surface to the other by direct radiation, and about 40 percent is transferred by conduction and circulation of air. The width of the air space

effects the amount of heat which is transferred by convection, but does not effect that part which is transferred by radiation. Thus, as the width of the air space is decreased below about ¾-inch the amount of heat transferred by convection and conduction begins to rise and at the narrower widths it increases very rapidly. From approximately ¾-inch upward the total heat transfers remains substantially constant so long as all other conditions excepting the width remain the same. Thus, in so far as width is concerned an air space to have its full value should be at least ¾-inch wide (Figure 3).

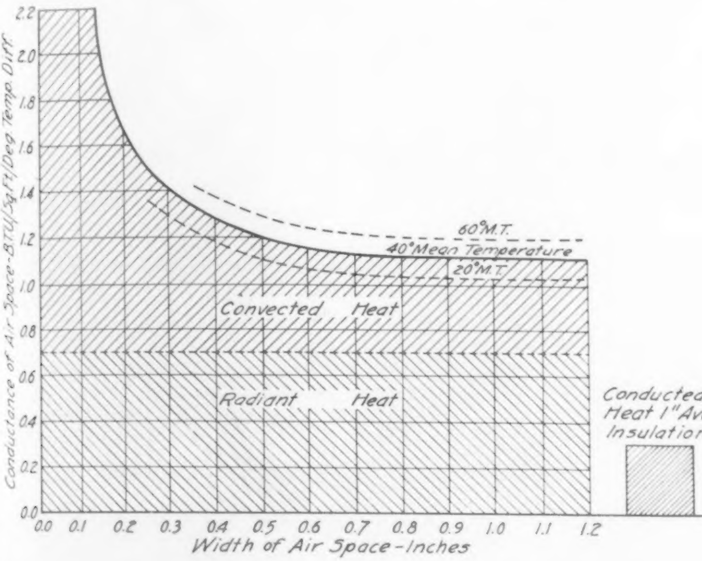

FIG. 3. Relation between width of air space and heat conducted through air space by radiation and by convection. Air space lined on each surface with average building material having emissivity coefficient of about .90.

The amount of heat transferred by radiation depends upon a surface quality known as its emissivity; that is, the percentage of heat which a surface will radiate in comparison with a dead black surface under exactly the same temperature conditions. The emissivity of ordinary building materials such as wood, paper, brick, etc., usually runs from 90 to 93 percent. Certain other materials such as highly polished metals may have very low emissivity coefficients, and aluminum or copper foils, often quoted as good insulators, have emissivity coefficient of approximately .05. In other words, a surface lined with aluminum foil would transmit only 5 percent as much radiant heat as the same surface would radiate if covered with a dead black material. Thus if aluminum foil or some similar material is used to line the surfaces of an air space the 60 percent of heat which was transferred by radiation would be greatly reduced and,

therefore, the over-all value of the air space correspondingly increased (Figure 4). The foil does not affect the amount of heat transferred by convection, and the application of the foil to one surface of the air space is nearly as effective as is the application to both surfaces. This is due to the fact that the heat radiating and receiving properties of the material are the same and if one surface lining stops 95 percent of the radiant heat the second surface lining can

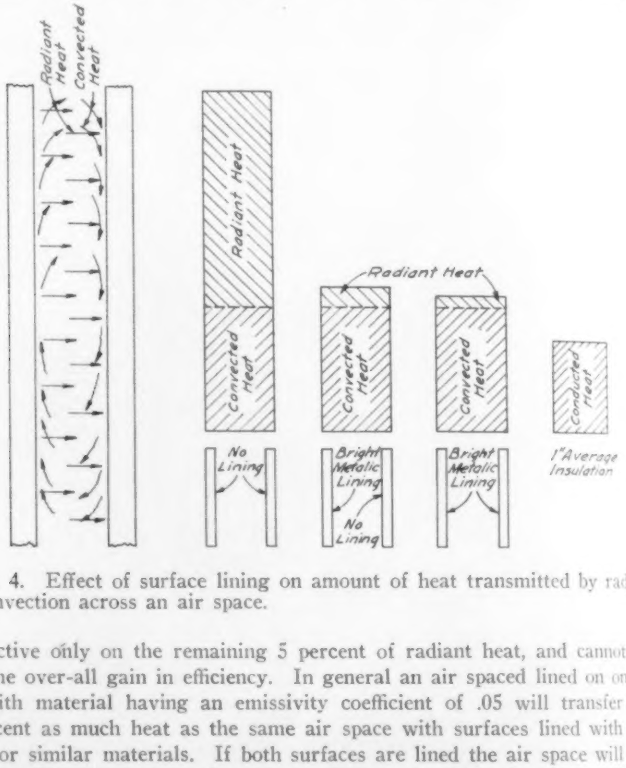

FIG. 4. Effect of surface lining on amount of heat transmitted by radiation and convection across an air space.

be effective only on the remaining 5 percent of radiant heat, and cannot show the same over-all gain in efficiency. In general an air spaced lined on one surface with material having an emissivity coefficient of .05 will transfer about 40 percent as much heat as the same air space with surfaces lined with wood, paper, or similar materials. If both surfaces are lined the air space will transfer about 36 percent as much heat as a space with unlined surfaces. In considering this high percentage in the reduction of heat due to the surface lining one must still be cautious not to overrate the value of an air space. An air space lined with ordinary material is equivalent to approximately .3 inch of good insulating material, and the same air space lined on both surfaces with material having a low emissivity coefficient is equivalent to about .8 inch of an insulating material; thus the addition of foil is equivalent to adding .5 inch of insulation

The value of air space insulation within a wall cannot be considered independent of the other parallel paths through which heat may flow. Heat will be conducted from surface to surface throughout a wall by the paths of least heat

resistance. If the interior part of a wall is built up partly of air spaces and partly of solid materials the largest percent of the heat may go through either path which happens to have the lowest heat resistance. Thus it is useless to add thermal resistance to an air space when there are high thermal conductivity paths through which the heat may flow around the air space. This condition is apparent in some types of hollow tile wall construction (Figure 5). A tile

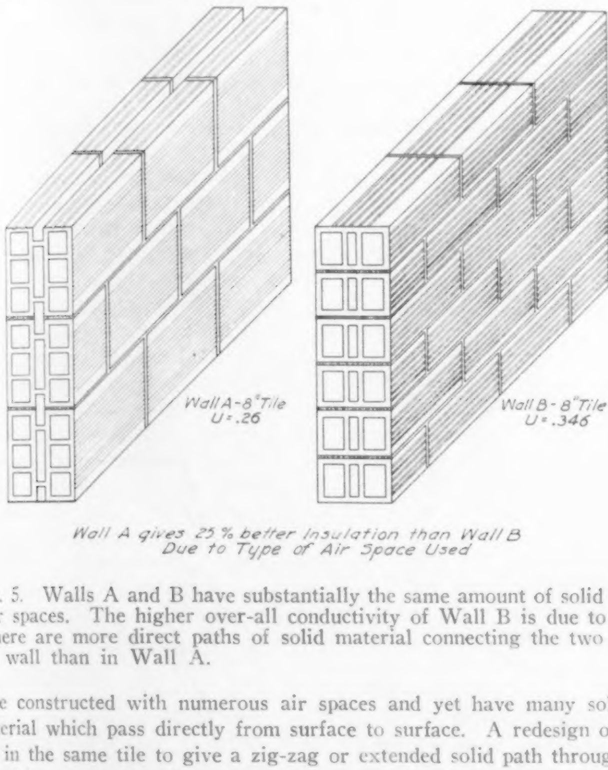

FIG. 5. Walls A and B have substantially the same amount of solid material and air spaces. The higher over-all conductivity of Wall B is due to the fact that there are more direct paths of solid material connecting the two surfaces of the wall than in Wall A.

may be constructed with numerous air spaces and yet have many solid paths of material which pass directly from surface to surface. A redesign of the air spaces in the same tile to give a zig-zag or extended solid path throughout the tile partition connecting the two surfaces may reduce the thermal conductivity by as much as 20 or 25 percent without adding or subtracting any material from the construction. To be effective an insulating material or insulating type of construction must be so used as to cover the full area of the wall, or at least to include all areas of high thermal conductivity. The application of insulating materials is often of more importance than the insulating value of the material itself.

AIR FILTRATION THROUGH BUILDINGS

A second factor which contributes to the direct loss or gain of heat through the walls of a building is that of air filtration or leakage through the exterior

walls and around loose fitting doors and windows. On windy days this may in many instances be greater than the direct loss due to temperature differences between inside and outside of building. For an average house the loss of heat for still air conditions will be more than doubled by a 30-mile wind velocity without any change in outside temperature. Wind velocity has some effect in increasing the direct transmission but has the greatest effect on the air leakage through the building. For the better types of construction it is now becoming the practice to use weatherstrips and closely fitting doors and windows in order to reduce the leakage factor.

THE MOISTURE PROBLEM

When we think of constructing a building to protect us from moisture we visualize protection against rain and free moisture from the outside, and indeed our efforts to build a structure which will guard against moisture from this source has been partly responsible for a new type of moisture problem which has only recently come into prominence. This problem comes from the fact that moisture may exist as a vapor mixed with the air and may under certain conditions be condensed out as free water. The amount of water vapor which may be contained in a given volume of air depends entirely upon its temperature. As a matter of fact the vapor may exist in the space equally well without the air, although it is convenient to think of it as carried by the air. The maximum amount of vapor which may be contained in any space increases as the temperature is increased. If a given space contains the maximum unit weight of vapor for a given temperature it is said to be saturated. If it contains only half of the amount that it is capable of maintaining it is said to be 50 percent saturated. The ratio of the amount of vapor in any given space to the maximum amount that could be contained in that space is spoken of as relative humidity. Since the maximum amount of vapor which can be carried in a given space is decreased as the temperature is decreased it is obvious that if a space saturated with vapor is cooled, some of this vapor will be condensed in the form of free water. Also, if a space which is partially saturated with vapor is gradually cooled it will ultimately reach its saturation temperature after which further cooling will condense out some of the water vapor. If the final temperatures are below the freezing point of water, ice will be formed. The amount of vapor within a house is increased by the normal living processes. At the same time it is reduced by the addition of outside low humidity air which is carried into the house by infiltration processes. Ultimately a balanced condition is reached and under ordinary conditions its dew point temperature is well below the temperature of the inside surfaces of the walls.

Two general changes have been taking place during recent years, both of which have had a tendency to increase the normal amount of moisture to be found in the average home. Better building construction, the addition of weatherstrips, and tigher fitting doors and windows have resulted in a reduction in the amount of air transferred through the outside walls of a building. Thus by normal processes the relative humidities within the home are allowed to build up to a much higher percentage. In addition to this a great deal has been said recently about the extreme low humidities which are often found in our houses

in cold climates and the effect which these low humidities may have on health. This has resulted in a popular demand for artificial humidification. It is difficult to evaluate the combined effect of these two causes on the percentages of relative humidity carried, but it is safe to say that in many instances the humidities have been raised from a normal of 20 to 30 percent in extreme weather to as much as 40 to 60 percent in some cases. These higher relative humidities give higher dew point temperatures and a greater probability that condensation may take place. The most likely surfaces for condensation are the inner surfaces of glass windows. Following this are the inner surfaces of double glazed windows, cold exterior walls such as unheated closets, exposed attics, etc.

Condensation is not confined to the interior cold surfaces of buildings. Water vapor will penetrate many building materials and in some cases it will penetrate walls which are impermeable to the passage of air. As the vapor passes beyond the interior surface of a wall it gradually comes in contact with colder materials, and if it is not sufficiently vented out to the cold side the vapor density in the interior sections of the wall may reach a point at which condensation will take place. Evidently the worst conditions are those of high relative humidities within a building and prolonged cold outside temperatures. Under such conditions frost may accumulate within a wall for long periods of time, after which a rising outside temperature may melt the frost at a much greater rate than the water can be evaporated and carried out of the wall.

In an effort to protect buildings from the outside moisture and weather it has for many years been customary to use some kind of a good building paper on the sheathing or near the outside surface of the wall. The papers as originally used were fairly good barriers against the transfer of air and water, but not particularly efficient against the transfer of water vapors. Recently better papers have been developed and many building papers now on the market are efficient barriers against water vapor and when placed on the cold side of a wall prevent the escape to the outside of vapor which may be transmitted to the inner section of the wall. This means that there will be a higher vapor pressure within the wall and a greater possibility that condensation will take place. The addition of insulation is another factor which increases the possibility of condensation within a wall. Many insulating materials do not form any particular resistance to the travel of vapor. When these are placed in the wall the temperatures of the outer sections will be reduced and thus will still further increase the possibility of condensation of moisture at these parts.

There are at least four causes which have brought the condensation problem into the foreground during the past few years. First, the addition of artificial humidity has become more common practice. Second, the addition of weatherstrips and better building construction has reduced the infiltration of air between the inside and outside, which has resulted in a greater natural build-up of humidity on the inside of the structure. Third, better building papers used on the outside of the structure have resulted in greater resistance to the passage of vapor through the outside surface of the wall. Fourth, the addition of insulation has in many cases reduced the temperature of outer parts of the structure, thus giving colder surfaces for the condensation of vapor.

THEORY OF VAPOR TRANSMISSION

Until recently the theory covering the transmission of vapor through building construction has been given but very little consideration. A theory that has been commonly advanced is that vapor will flow through materials in direct proportion to the vapor pressure difference on the two sides of the material

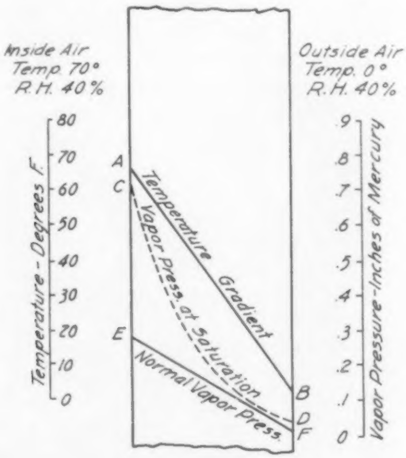

FIG. 6. Wall built of homogeneous material which is non-hygroscopic but permeable to water vapor. C-D represents maximum vapor pressure than can exist in wall without condensation. E-F represents probable vapor pressure that will be established by atmospheric conditions on the two sides of the wall. No condensation will occur under these conditions.

and inversely proportional to a property of the material which may be termed its vapor resistance. This law is similar to that governing the flow of heat through materials. It omits, however, the fact that all materials do not behave the same in the presence of water vapor and, further, that the state of the vapor may be changed in its transmission through a material or combination of materials. Vapor may be transmitted from the air on one side to the air on the other side of a wall either in the form of a vapor throughout its passage or it may be condensed and be transmitted as free water through part of its path. The condensation may be due to the fact that the temperatures within the wall are below the dew point temperature of the vapor, or it may be due to the hygroscopic nature of the material through which the vapor is passing.

In general materials which will transmit moisture may be divided into three classes. First, those materials which are non-hygroscopic and permeable to water vapor. Second, those materials which are hygroscopic and impermeable to water vapor; and third, those materials which are both hygroscopic and permeable to water vapor (Figure 6). For those materials which are non-hygroscopic and permeable to vapor it appears that the flow should be directly proportional to the vapor pressure differences between the vapor at the two

surfaces of the material. The vapor resistance will be different for different types of materials and will probably depend somewhat on the cellular formation within the material (Figure 7). The vapor will travel in the direction of vapor pressure drop through the material, and if the temperatures at all points through the wall are above the dew point temperature of the vapor at these points there will be no condensation. If, on the other hand, the vapor pressure

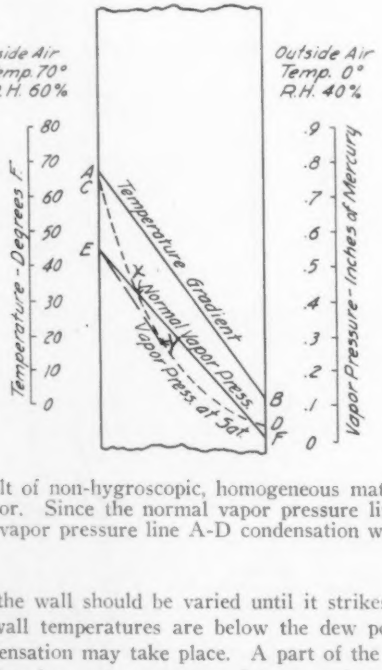

FIG. 7. Wall built of non-hygroscopic, homogeneous material which is permeable to water vapor. Since the normal vapor pressure line E-F crosses the maximum allowable vapor pressure line A-D condensation will occur within the wall.

established through the wall should be varied until it strikes some point in the wall at which the wall temperatures are below the dew point temperature of the vapor, then condensation may take place. A part of the vapor may pass on through the material and a part may accumulate as moisture or frost, depending upon the temperatures. If a material having a high resistance to vapor is placed on the high vapor density side of this type of a wall the vapor density throughout the wall will be reduced and there will be less likelihood of condensation within the wall (Figure 8). If on the other hand, the vapor resisting material is placed on the low vapor density side of the wall the vapor density will be built up within the wall and there will be a greater possibility that condensation will occur (Figure 9).

For the homogeneous-hygroscopic materials which are impermeable to water vapor the vapor cannot pass through in its original state but it may be absorbed through one surface, transmitted as a liquid to the opposite surface, from where it is reevaporated. Materials of this nature have a moisture equilibrium content when in contact with water vapor which depends not upon the absolute vapor pressure but rather upon the relative humidity of the vapor in

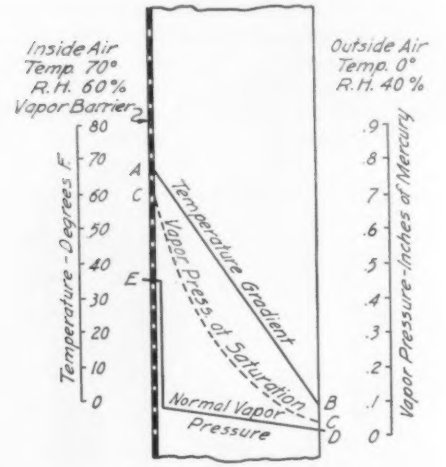

FIG. 8. Wall built of homogeneous, non-hygroscopic material permeable to water vapor. Vapor barrier placed on high vapor pressure side of wall. No condensation within wall.

contact with the material. If we assume a wall that is constructed of wood to be in contact with air on the left hand side which is at 80° F. and 50 percent

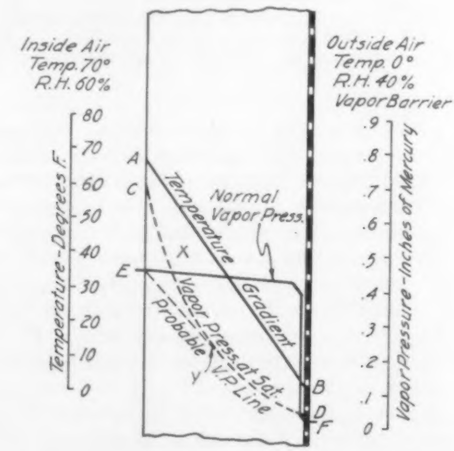

FIG. 9. Wall built of homogeneous, non-hygroscopic material permeable to water vapor. Vapor barrier placed on low vapor pressure side of wall. E-Y-F represents probable vapor pressure gradient established by atmospheric conditions on two sides of walls.

relative humidity, and with air on the right hand side at 30° F. and 70 percent relative humidity, the moisture equilibrium of the wood will be 9 percent by weight on the left hand side and 13.5 percent on the right hand side. The moisture should therefore flow from the right to left through the wall. The vapor pressures corresponding to temperature and humidity conditions on the two sides of the wall are .51 and .115 inch of mercury for the left hand and right hand sides respectively. The moisture travel through the wall would, therefore, be in the reverse direction from the vapor pressure drop. Many

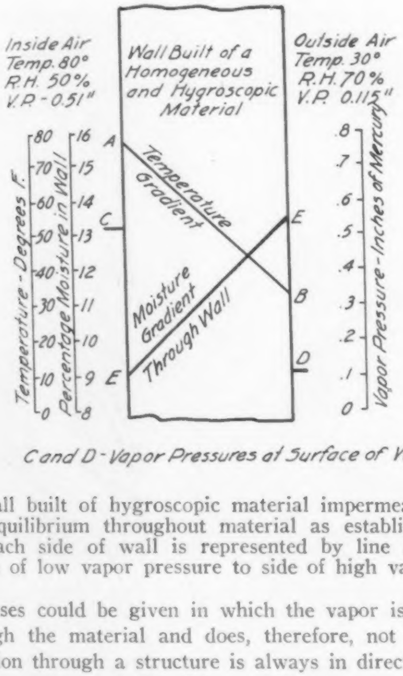

FIG. 10. Wall built of hygroscopic material impermeable to water vapor. The moisture equilibrium throughout material as established by atmospheric conditions on each side of wall is represented by line E-F. Moisture will travel from side of low vapor pressure to side of high vapor pressure.

other similar cases could be given in which the vapor is changed in state as it passes through the material and does, therefore, not follow the law that vapor transmission through a structure is always in direct proportion to vapor pressure drop across the material (Figure 10).

INVESTIGATION OF CONDENSATION PROBLEM

In order to get some practical information concerning the condensation of moisture within walls a large well insulated test room 30 feet square and 25 feet high has been constructed and provided with artificial refrigeration sufficient to maintain the air in the room as low as 25° below zero for prolonged periods. Small test houses have been built in this room and supplied with conditioned air for which the temperature and relative humidity may be controlled at any desired point. These houses have been built with different types of materials and have been so constructed that the walls may be removed or taken down during a test period to examine the interior parts of the struc-

ture for the accumulation of moisture or frost. By this method it has been possible to study the effect of moisture and temperature on walls built of different materials and combination of materials over long periods of exposure. For instance, in several tests small houses have been maintained with outside temperatures of —20° F. for as much as twenty days at a time, with high interior relative humidities. Severe conditions have been purposely established in order to test the different types of construction under breakdown conditions (Figure 11).

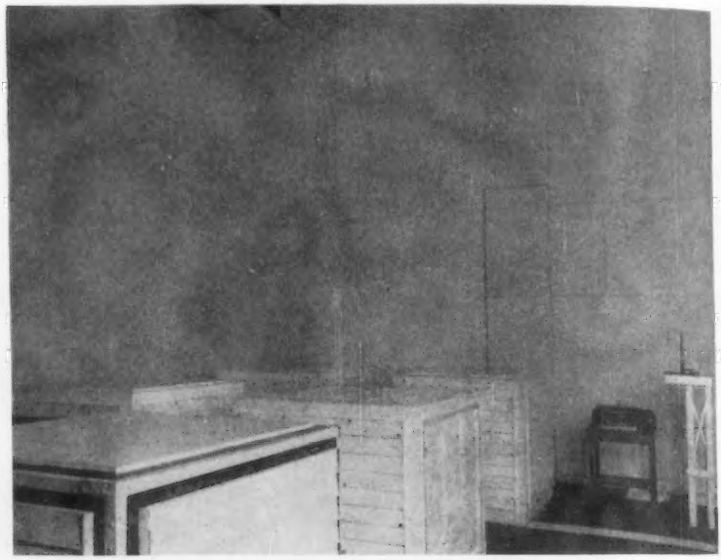

Fig. 11. View of cold room showing small test houses in place. The room is 30 feet square, 25 feet high and may be cooled down to 25° below zero.

As there are several causes of condensation there are likewise several practical remedies. For the house which has been completed and for which changes would be impractical or impossible the most effective method is to lower the relative humidity in the house. If moisture or frost accumulates within a wall it represents the difference between the amount of vapor which passes into the wall and that which passes out through the exterior surface. Since the amount which passes into the wall through the interior surface is substantially proportional to the relative humidity carried within the building a reduction in the relative humidity will cause a proportional reduction in the amount of vapor carried into the wall. If all other conditions except the relative humdity remains constant the amount of moisture carried out of the wall will remain constant and the percentage reduction in the moisture accumulation will be greater than the percentage reduction in the relative humidity. Since

high relative humidity is so often the cause of condensation difficulties it should be the first point to investigate.

TABLE I

CONDENSATION ON INNER SURFACE OF SHEATHING FOR DIFFERENT TYPES OF FINISHES ON INTERIOR SURFACE OF PLASTER

Finishes on inside surface of plaster	*No. of tests*	*Outside air temp. —° F.*	*Inside surface temp. of sheathing —° F.*	*Condensation on sheathing grs./sq. ft./24 hrs.*
Unfinished	3	—19.5	—0.2	2.15
	3	+10.0	22.8	1.40
Two coats seal coat paint..	1	—19.5	0.8	0.20
	1	+10.0	23.6	0.00
Two coats white flat paint.	1	—19.5	—1.5	0.24
	1	+10.0	20.6	0.00
Two coats aluminum paint.	1	—19.5	0.5	0.25
	1	+10.0	23.6	0.00
One coat asphalt applied hot	1	—19.5	1.1	0.13
	1	+10.0	23.3	0.00
One coat seal coat paint, two coats white flat paint....	1	—19.5	1.8	0.23
	1	+10.0	22.5	0.00
One coat seal coat paint, two coats aluminum paint....	1	—19.5	3.9	0.16
	1	+10.0	24.3	0.00
One coat glue size with plain wall paper.........	1	—19.5	—0.9	2.11
	1	+10.0	22.2	1.11
One coat glue size with dull surface treated canvas wall covering.......	1	—19.5	0.4	0.64
	1	+10.0	22.3	0.10
One coat glue size with glossy surface treated canvas wall covering....	1	—19.5	0.7	0.47
	1	+10.0	21.7	0.01
One coat glue size with duplex crepe paper......	1	—19.5	—0.2	0.32
	1	+10.0	21.8	0.00

Note.—Inside air conditions 70° F. and 40% R.H. All walls constructed with 2″ × 4″ studs spaced 16″ on center; metal lath and plaster on interior surface; 8″ Ponderosa pine shiplap, building paper and 6″ redwood siding on outside; 3⅝″ Mineral Wool between studs; surface finish as specified.

If a structure has been completed and condensation develops it may be possible to find a remedy in the application of some vapor resisting material as a finish on the inside surfaces of the wall. There are many such materials in the form of paint, and to a certain extent fabrics and papers. As a general thing, however, the ordinary wall paper is not a vapor barrier. A list of interior finishes which have been found effective as vapor barriers are shown in Table I. The last column of this table gives the relative value of the different types of finishes in terms of grams of moisture condensed on the inner surface of sheathing per square foot per twenty-four hours under constant test conditions. As will be noted many of the oil paints give reasonably good protection from the vapor, although ordinary glue size and wall paper does but very little good. If a material can be applied to the inner surface of a wall which will prevent 80 percent of the vapor from traveling into the wall it will probably eliminate all possibilities of condensation.

If a wall is to be constructed the logical procedure is to place some vapor proof material on the warm side of the wall and to be cautious about placing too good a barrier on the cold side. In other words the correct principle is to prevent the vapor from traveling into the wall and once it is in the wall to allow it to continue on through. Many building papers have been found to be good vapor barriers. In general an asphalt saturated building felt is not particularly good, but a saturated paper which has a comparatively smooth and continuous glazed surface of asphalt or a duplex paper with a continuous sheet of asphalt between the two layers of paper will make a good barrier. One of the principal requirements is that the asphalt surface be continuous and unbroken. The reflective metal foils which are sometimes used in building construction are also good barriers. Some of the old types of building paper, such as rosin paper and saturated building paper, are not particularly good as vapor barriers but may be good exterior sheathing papers since they will make a good break for the wind and water but will allow some venting of the vapors which may accumulate within the wall. Table II gives a list of some of the paper barriers which have been found satisfactory. In this table the last column represents the relative value of the barrier when placed in a wall and shows the rate at which moisture was condensed on the outside surface of the sheathing with the particular barrier placed under the metal lath on the warm side of the insulation. In each case the walls were insulated with four inches of fill insulation.

A still further method of preventing condensation is to provide artificial ventilation through the exterior surface of the wall to assist in carrying out the vapors. This method proved very satisfactory in the case of attics which have the insulation placed in the ceiling of the upper floor and where cold attic temperatures are not a disadvantage. Tests have shown that a very small amount of ventilation may entirely clear up a severe attic condensation problem without seriously increasing the heat loss through the attic.

The question often comes up as to the possibility of condensation hazards in applying insulation to an old house. In this case the simplest method seems to be to use some type of fill insulation within the walls and perhaps on the upper floor ceiling. Insulations of this nature do not have any particular resistance to the passage of vapor and since their application means a lower

TABLE II

CONDENSATION ON INNER SURFACE OF SHEATHING FOR DIFFERENT TYPES OF VAPOR BARRIERS PLACED BETWEEN METAL LATH AND STUDS

Vapor barriers		*Outside air temp. ° F.*	*Inside surface temp. of sheathing ° F.*	*Condensation on sheathing grams/sq. ft./24 hrs.* *Test No.*	*Test result*	*Average of tests*
None	....	—19.5	—0.3	4	2.16	
	....	—19.5	—1.5	4	2.26	
	....	—19.3	1.3	8	2.02	2.15
None	....	9.9	23.0	7	1.02	
	....	10.1	22.8	20	1.55	
	....	9.9	22.5	7	1.65	1.41
Asphalt impregnated and surface coated glossy sheathing paper. Wt. of paper tested 51.9 lbs. per roll of 500 sq. ft.	Edges lapped not sealed	—19.5	—4.1	4	0.09	
		—19.5	—2.0	8	0.05	0.07
		9.9	20.5	7	0.00	0.00
	Edges lapped and sealed	—19.5	—3.5	4	0.02	0.02
		9.9	19.7	7	0.00	0.00
30-30-30 duplex. Two sheets of 30 lb. kraft paper cemented together with layer of asphalt, equal in wt. to 1 layer of paper. Wt. of paper tested, 58 lbs. per roll of 500 sq. ft.	Edges lapped not sealed	—19.5	—3.2	4	0.31	
		—19.3	0.7	8	0.20	0.25
		9.9	20.9	7	0.00	0.00
	Edges lapped and sealed	—19.5	—3.0	4	0.19	0.19
		9.9	20.7	7	0.00	0.00
Paper with rag felt base saturated with asphalt. Wt. of paper tested, 70.8 lbs. per roll of 500 sq. ft.	Edges lapped not sealed	—19.5	—2.2	4	0.52	0.52
		9.9	21.3	7	0.18	0.18
Duplex crepe paper. Wt. of paper tested, 40.7 lbs. per 500 sq. ft.	Edges lapped and sealed	—19.5	—1.8	4	0.09	0.09
		9.9	21.6	7	0.00	0.00

Note.—Inside air conditions 70° F., 40% R.H. All walls constructed with 2" × 4" studs spaced 16" O.C.; metal lath and plaster on interior surface; 8" Ponderosa pine shiplap, building paper, and 6" redwood siding on outside; 3⅝" Mineral Wool between studs; vapor barriers as specified.

outside sheathing temperature the possibilities of condensation are naturally increased. This does not mean, however, that condensation will result as it will depend upon the conditions carried within the house and the outside weather temperatures. The cause is not in the insulation itself as is sometimes supposed, but it is due to the fact that the application of the insulation prevents the heat from escaping through the walls to the exterior surfaces. In most cases where condensation has occurred an investigation will show that high relative humidities have been carried within the structure.

When fill insulation is added between the joists of the upper floor ceiling the temperature of the attic air is reduced and with outside weather temperature of —20° F. the temperature at the under side of the roof boards is reduced as much as 15 or 20 degrees. If no vapor resisting material is added to the upper floor ceiling obviously there will be no great reduction in the amount of vapor passing through to the attic, and since the under side of the roof boards are much colder there will be more chance of condensation. As in the case of the side walls this may be remedied by adding some type of vapor barrier under the ceiling, or it is often possible to add a vapor barrier paper between the joists before the insulation is applied. If condensation develops in an attic after the structure is completed a practical solution is to provide small attic ventilators in gables at opposite ends of the roof. Such ventilators if arranged to give reasonable circulation of a small amount of outside air through the attic are very effective in reducing the accumulation of frost on the under side of the roof boards. If the frost is allowed to accumulate through a prolonged cold period it will melt either due to warmer outside temperatures or to the radiant heat from the sun and the water may run down the ceiling or side walls and ruin the decorations. Condensation of this nature is often mistaken for roof leakage.

SOLAR RADIATION

In many warm climates solar radiation is one of the most difficult elements to deal with. The radiant heat from the sun at maximum intensity on a surface normal to the sun's rays is equivalent to the heat from a continuous blanket of 100-watt lights spaced approximately 13 inches apart in each direction. In other words, all of the heat produced by this continuous plane of lights would be equivalent to the heat from the sun which shines onto a surface normal to its rays. The maximum intensity of the sun's heat is at midday. However, this intensity remains substantially the same for five hours during the middle of the day. The intensity on any surface which is other than normal to the sun's rays is reduced due to the angularity of the sun's rays to that surface but it still represents a large amount of heat.

When radiant heat from the sun strikes the surface of a building a part of it is absorbed by the surface and a part of it is reflected. The amount absorbed depends upon the character of the surface. Although color is not the only surface characteristic which determines the amount of heat that a material may absorb it may in general be assumed that very light colored materials such as light colored stone, cement, white or cream colored paint, etc., will absorb about 40 percent of the radiant heat; medium dark surfaces such as asbestos

shingles, unpainted wood, brown stone, brick, and red tile will absorb about 70 percent; and very dark surfaces such as slate or tar roofing, or very dark paint will absorb about 90 percent of the total radiant heat. Of the amount absorbed into the surface a portion is convected away by the outside air currents which come in contact with the surface and a portion is conducted into the material from where it may be transmitted into the building by both radiation and convection. On a hot summer day the amount of radiant heat absorbed from the sun's rays is sufficient to raise the temperature of a tar and gravel roof to as much as 60 degrees above air temperature. In other words, with 90 degrees air temperature a roof surface may easily reach 150° F. This means that an enormous amount of heat is conducted through the roof to the interior part of the building. Due to the mass of material in the roof and its resistance to heat flow the effect of this heat is often delayed until many hours after the most intense sunshine. Thus heat which is accumulated in a roof during the middle of the day may not show its full effect into the building until nine or ten o'clock in the evening. It is for this reason that the upper floors of apartments and hotels which are covered with flat roofs often become unbearably hot in warm weather.

There are several methods by which the effect of the radiant heat from the sun may be reduced. First, a light colored surface such as white paint and, if practical, aluminum and similar metals with highly reflective surfaces are very effective in reflecting the heat from the sun and thus preventing its absorption by the surface. Second, it is possible to conduct the heat from the surface to the outside air by artificial air currents passing over the surface. A wind velocity of fifteen miles per hour over the surface of the roof will conduct four times as much heat from the surface as would be conducted from it by normal still air. A water spray over the surface may serve to lower the surface temperature even below the air temperature, and in some instances it may serve as an effective cooling method. In case there is an attic space under the roof it is often effective to ventilate this attic space and thus prevent the high temperatures of the roof from penetrating the ceiling material over the upper floor. Attic ventilation may even be profitable at midday when the outside air temperatures are the highest as attic air tempetratures often reach from 30 to 50 degrees above outside air temperatures. Logical methods are, first to prevent the heat from the sun from entering the surface of the roof; second, to conduct to the outside any heat which does enter the surface and prevent it from getting into the living quarters. The average daily air temperature variation from the warmest period of the day to the coolest part of the night is approximately 15° F. By proper control of the use of night air it is often possible to cool certain parts of the building during the night and to cut this air circulation off during the day and use the accumulated cooling effect in the building. An intelligent use of natural preventative methods such as shielding the surface from the sun, conducting the heat from the outer surface by air currents or water spray, and ventilating the inner part of the structure and attics may do much to eliminate the effect of the intense heat from the sun on the surfaces of roofs and other parts of a building.

Unprotected window glass is particularly vulnerable to the heat from the sun. At least 95 percent of the radiant heat from the sun's rays will pass directly through the ordinary unprotected window glass and be absorbed by the materials within a building. This absorbed heat may be partly reradiated but unfortunately only a very small percentage of the low temperature radiant heat will pass directly through the window and, therefore, it is trapped in the room.

The best method of controlling the heat which may enter directly through glass windows is to shield the windows from the sun on the outside. An awning or Venetian blind placed on the outside of a window forms a very effective shield. Experiments have shown that awnings on the outside of a window which give reasonable coverage may reduce the total heat to about 22 percent as compared with approximately 95 percent of the sun's heat which will pass through the unprotected window. An awning covered with an aluminum finish is slightly better than a plain canvas awning as it has a tendency to reflect a greater percentage of the direct rays from the sun. Venetian blinds placed on the outside and adjusted to prevent the direct rays from passing between the slats will also reduce the total heat passing through the window to approximately 22 percent of the total. If, however, the Venetian blinds are placed on the inside of the windows the heat is only reduced to about 58 percent. In this case the direct rays from the sun pass through the window, strike the reflectors of the Venetian blinds, and while the Venetian blind may prevent the heat rays from passing directly into the lower part of the room a large percentage of the heat still remains in the room and ultimately increases the interior air temperature. Window shades placed on the inside of a window will reduce the total heat projected into the room, but these act similarly to the inside Venetian blinds. The sun's rays after entering the room heat up the shade, this heat being carried by convection currents into the room. An aluminum shade fully drawn will permit about 45 percent of the heat from the sun to enter the room and a buff shade half drawn will permit 68 percent to enter. In general the best method of protecting windows against sunshine is to shield them and reflect the direct heat rays away from the windows. After the rays of heat have passed through the window only a small percentage can be reflected out through the window to the outside.

A satisfactory house must be constructed of materials which may be combined to resist the various climatic elements on both the outside and inside of the house. In general these elements are wind, air temperature, moisture, and sunshine. The house must be economical to build and maintain and yet be durable. Science has developed many materials and methods of application to meet the practical requirements, but the building of a home is much more than the assembling of materials. It requires the imagination of the architect, the planning of the engineer, and the skill of the experienced builder to assemble these materials in such manner that the finished home will not only fulfill its practical requirements, but that it will blend harmoniously with its surroundings and be an expression of the art and culture of the age to which it belongs.

RESEARCH AND THE GRADUATE STUDENT[1]

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Research workers are valuable largely for two reasons: (1) for the ideas which they possess, and (2) for the things they can accomplish. In a recent number of *Scientific Monthly* we have Millikan's statement for the fact that as successful a research worker as Michelson regarded ideas and the knowing of what problems to attack as in general of more value than the mere steps by which the ideas are carried out. However, Michelson himself demonstrated the value of both types of service. The ancients had some excellent ideas, but they attempted to establish them by argument instead of by experiment. Without use of development the best of ideas is of little value.

But how shall a young worker break into the field? What are the steps by which he may establish himself as a producer of knowledge? Perhaps precise answers should not be attempted, but the general direction of endeavor is clear. Fortunately, there is no dearth of material for investigation. The unknown abounds everywhere—choose a problem and endeavor to solve it. But before a problem is studied intensely it is essential to become acquainted with previously acquired knowledge in that field. The future is built upon the past just as truly in science as in other lines of endeavor. Our worker goes to the library to find out what has been published on the subject. He talks with other workers. His readings and conversations should suggest one or more possible ways of approach. But probably he lacks suitable methods—that is the reason why nature still holds the answer to so many problems. And so he must digress temporarily from his main objective to develop a suitable method. After a time he has a method to try—perhaps it fails, he tries another, and so the investigation proceeds. As failures occur new ideas arise, and if one is fortunate a solution ultimately takes form and the answer finally is achieved. But a solution to one problem always raises a number of related problems which likewise require a solution and the process must needs be repeated *ad infinitum*.

And what of the worker himself—what qualities are engendered by this ceaseless quest for knowledge? A good investigator must learn to do a lot of work—Edison characterized genius as one-fourth inspiration and three-fourths perspiration; he must possess an infinite patience—Darwin worked for twenty years before he risked publication of his ideas concerning evolution; he must generate his own enthusiasm; originate many or most of the ideas with which he works; criticize his own procedure; profit by his own mistakes, and recognize his limitations. He must see with his mind as well as with his eyes—imagination is vital to success.

Perhaps I have discouraged my listeners and our prospective future investigators by the apparently superhuman qualifications I have proposed. I hope

[1] Fourth annual lecture given by the Sigma Xi Club of West Virginia University for graduate students in science.

not. Many individuals have qualified in the past, and many more will do so in the future. Probably no person here tonight is possessed, in full degree, of all the characteristics I have enumerated and, on the other hand, probably no one is entirely lacking in any of them. Certainly all of these traits may be acquired by cultivation.

In the large lecture room of the chemistry building some two months ago, a prominent young research worker stated that the main functions of a university are three, *viz.*, the creation, the preservation, and the dissemination of knowledge. This discussion deals primarily with the first of these, *i.e.*, the creation of knowledge, but I shall have a few statements to make regarding dissemination also.

Ideas concerning the prosecution of research are many and varied. We might illustrate two somewhat divergent lines of thought by quoting directly from two contemporary workers, each highly successful in his field. Charles F. Kettering, director of a great industrial research organization says, "Motion is more important in research than intelligence because you cannot tell what is going to happen." He, also, is authority for the statement that "intelligent ignorance is the first requirement in research."

On the other hand, Dr. George R. Minot, Professor of Medicine at Harvard University, and corecipient of the Nobel prize in medicine in 1934, says, "Quantity does not supplant quality.—The foundation of research work lies in the quality of the minds of the investigators and the freedom and tranquility permitted for the use of their abilities. Free choice of problems, and free choice to follow leads disclosed, must be the privilege of the experienced investigators."

It is a fortunate thing for society that accomplishment in research is not restricted to a very few nor reserved for the politically or financially favored. It is not confined to any race or any creed. Russian, German, Japanese, Italian, Frenchman and Englishman, Catholic, Protestant, Jew and Hindu, all have contributed. Faraday was the son of a blacksmith, Pasteur the son of a tanner, Steinmetz was chased out of Germany for being a Socialist, and Pupin was a poor immigrant from Yugoslavia to America and worked as a farm hand in Maryland and Delaware. What an array of characters, personalities, and backgrounds the roster of science holds! Investigation may be undertaken by anyone who is willing to subject his mind to a rigorous system of thinking and his efforts to a search for truth.

For the encouragement of those students who may not be receiving as good grades as they would like to receive I would point out that some of our greatest benefactors have not been brilliant students in the university. Pasteur's mind worked so carefully that he was considered slow, and in group of examinations he was listed as "mediocre" in chemistry, and stood fifteenth among twenty-two candidates for the normal school. Partly in derision and partly in discernment of his ability his fellow students called him a "laboratory pillar." He could accomplish things in the laboratory better than he could satisfy the examinations of his instructors. He was not a brilliant student but he did things for which the whole civilized world is grateful.

I do not wish to belittle our educational standards, but I do wish to emphasize the fact that every once in a while one of these quiet penetrating minds

breaks through the magma of contemporary murkiness and haze that surrounds a problem and grasps a clearer vision of the true structure beneath. This only serves to show us how faulty may be our standards of evaluation and how dull our own vaunted comprehension.

Paul Ehrlich was an indifferent student. When he was supposed to be dissecting he was making colored slides. His instructor let him go his own way. Perhaps in other laboratories he would have been failed outright. Finally he was given his medical degree partly on the assumption that he would never put it to practical use. How fortunate for medicine that he ignored dissection and that he was allowed to satisfy his curiosity with dyes and stains. His methods are basic in hospital technic everywhere today. Nor is that all. Salvarsan or "606" and neosalvarsan or "914" are mileposts in Ehrlich's trial and error series.

And that brings me to another point. Accomplishment in research seldom springs full-fledged into existence, but usually develops slowly, by the efforts of many, into a useful whole. Ehrlich's work on salvarsan was really the result of the combined efforts of a whole staff of chemists, bacteriologists, and skilled medical men. So it is with most lines of progress.

Our own federal government has only recently established four regional laboratories for research in this country. The one for this region will be located at Philadelphia. Large sums of money will be spent in the development of research relating to agricultural products, and the average citizen inquires, "Is the money being expended wisely?" Of course prediction as to accomplishments in these new laboratories is out of order at this time. Evaluation of research in agriculture must be based upon the older work of the United States Department of Agriculture and the State Experiment Stations. I shall take an illustration from the latter.

The Iowa Agricultural Experiment Station was organized at the same time as the West Virginia Station in 1888, fifty-one years ago. In an early report of the first director of the Iowa Station you will find these words, "We expect to be disappointed very often in the results of our experiments, but hope to strike a lead once in a while, which will advance the agricultural interests of the state." Two years later in Bulletin No. 10, published in 1890, these words were written by the same man: "From 1850 until 1870 oats and spring wheat were injured but little by fungous diseases or insects, and it was but seldom that they did not produce good crops; but from the latter date until now (*i.e.*, from 1870-90) they have been unreliable and unprofitable.—From the frequent partial failures of our oat crops on account of rust, and the rapid deterioration of good varieties which we have imported from the best oat countries, we can draw no other conclusion than that Iowa is not a good oat state." Contrast that picture with the present situation. Today, forty-nine years later, Iowa is the largest oat-producing state in the United States, and is producing approximately one-sixth of this country's oat crop. The oat acreage of Iowa is well over one-third of the entire land and water area of West Virginia, and this in a state thougth to be unsuited to the production of oats. I do not know the names of the men who have brought about this change, but I will venture to guess that many indivduals have participated in the breeding, selection, testing, and

treatment of the oat varieties being grown in Iowa's crop today, and that the total cost has been returned many times in the increased value of the crop produced.

In his essay on "Criticism," Alexander Pope wrote, "One science only will one genius fit; so vast is art, so narrow human wit,"—and in general that is quite true, but there have been some notable exceptions. Helmholtz started out as a physician, had a remarkable career as a professor of physiology and then became an outstanding physicist.

Even in our own day it is possible for a student to change fields of endeavor and be successful. An outstanding example of this is found in the work of Doctor Urey. Everyone knows that Dr. Urey was Nobel prize winner in chemistry in 1934. But it is not so generally known that he received the B. S. degrees from a comparatively small school, the University of Montana, in 1917, with a major in zoology. He was an instructor there from 1919 to 1921, and thirteen years later he received the Nobel prize for the discovery of heavy hydrogen. In fifteen years he changed professions and won a Nobel prize.

A few moments ago I stated that after the expenditure of much thought and effort if the research worker were fortunate a solution would eventually take form. But there will still be difficulties to be overcome and pitfalls to be avoided. The scientist is interested in having his work accepted for what it is worth but for its true worth only. He dislikes overstatement, misinterpretation and exaggeration even more than he does lack of recognition. It may seem strange that I should mention this, but it occurs more often than is ordinarily realized, and particularly in those lines of work where utilitarian values and commercial utilization are involved. Ideas are seized upon by newspaper reporters, promoters and persons interested in exploitation rather than in facts. Premature statements are made by individuals having no connection with, and frequently no accurate knowledge of, the problem.

Within the last three years at least two such instances have occurred in this institution. In the fall of 1936 certain newspapers carried articles with such statements as these: "Scientists at the dairy farm of West Virginia University have been playing some queer tricks with some of the sleek cows belonging to the state. For weeks they have been giving the animals generous drinks of lemonade and tomato juice. Strangely enough the subjects of the experiment seemed to like the taste of the lemons and the thick red juice of the tomato. The scurvy-preventing vitamin C content of the milk was noticeably increased, but this was not an unmixed blessing. Milk rich in vitamin C may be good for one's health, but it has an unpleasant taste. The West Virginia researchers have for years been investigating this matter of unpleasant flavors in milk—these latest experiments seem to suggest the remedy: Keep the vitamin C content of the cow's feed as low as possible without endangering the cow's own health." This is a garbled, inaccurate and misleading representation of fact.

More recently our own *Dominions-News* for February 10, 1939, carried an erroneous account of the efforts of two workers in our experiment station to color fruit. Under the heading "'U Men Find Way to Make Reddened Fruit'—Painted Exhibit is Being Shown at Farm Week," these statements occur: "Who believes that there are two men at West Virginia University who are helping

to paint the cheeks of the red apples in the display of Farm and Home Week in Morgantown? They have boiled and strained; weighed, measured and extracted gallons and gallons of juice.—If our grandmothers had all that juice to make into jelly we could feed all the refugees in Europe, that is if we had the bread.—If all the juices the chemists have boiled out to obtain the residue were made into jelly it would color the Thanksgiving tables of residents of the United States from coast to coast." From these statements one is tempted to suggest that somehow, somewhere, the apple juice may have aged and perhaps served purposes other than as a source of color.

Conversations with colleagues indicate that other workers on the staff have had experiences similar to those I have described. Of course, such accounts are properly discounted by anyone familiar with the field. Every freshman recognizes the distinction between qualitative and quantitative values, but these embellished accounts come to the attention of persons who are not qualified to distinguish properly between fact and fiction in the claims made. Science has done so many wonderful things that people are overcredulous and their faith is imposed upon. A few years back I was asked by a former member of this faculty if there really was a way to purify the water of the Monongahela River for household use and in the process to obtain a by-product dye which would pay for the purification. The idea had been gained from a newspaper report. During the last two years I have had several letters of inquiry concerning the growing of plants in solutions of chemicals, and one I recall asked for "full information" on how to grow vegetables on flat roof-tops and in other locations where soil is not available and where only chemicals are used. Only a few days ago an agricultural paper came to my desk with an editorial on "Growing Plants Without Soil." In it these statements appeared, "For those who are interested in the fascinating new method of growing plants without soil a complete kit is now available, which sells at $1.00. With the 'Chemi-Garden' all flowers, bulbs, and vegetables can be grown in the home with no more attention than with a pot of soil." Like many others I, too, indulge modestly, in the growth of a few vegetables, and I find a small plot of ground highly advantageous.

I am making a plea for conservativeness and moderation on the part of those who would carry the story of research to our main constituency, the great body of citizens who pay the bills. I am also directing the attention of young investigators to some of the dangers they may face in the misinterpretation, misapplication or exaggerated account of a task earnestly conducted and successfully accomplished.

On the other hand, one need not feel ashamed of his research no matter how modest his contribution. Truth is frequently difficult to find and sometimes still more difficult to recognize. There are many blind alleys in research work and a very great likelihood of error. Facts may be established only slowly. But sooner or later the isolated bits of evidence become sufficient to reveal the whole. I like to think of the work of Charles Darwin. He spent many years quietly collecting, organizing, and evaluating data, and then by the sheer weight of accumulated evidence from many lines of approach he forced

an unwilling world to think as perhaps no other man of modern times has done.

Some years ago I stood before a group of skeletons in the Field Museum of Natural History in Chicago. Mounted in a glass case side by side were the skeletons of a gorilla, a chimpanzee, and a human. Near me stood another man examining the display. He was a man in his late fifties—a person who had never had the advantages of education. Without any solicitation on my part, he said, "Those three fellows look a lot alike to me—maybe Darwin was right after all."

Publication of one's results is not the least of one's worries, particularly for beginners. Are the results worth publishing; if so, how shall they be prepared? Here the aid of an experienced worker frequently helps. Reviewers are critical; editors insist upon certain standard forms which differ from one journal to another; all insist upon brevity. To illustrate the trend toward conciseness of statement I shall read a few lines written humorously but, nevertheless, with considerable perception. This poem appeared in the *Canadian Public Health Journal* in 1936, and is entitled,

ADVICE TO AUTHORS

If you've got a thought that's happy—
Boil it down.
Make it short and crisp, and snappy—
Boil it down.
When your brain its coin has minted,
down the page your pen has sprinted,
If you want your effort printed,
Boil it down.

Take out every surplus letter —
Boil it down.
Fewer syllables the better—
Boil it down.
Make your meaning plain—express it,
So we'll know—not merely guess it,
Then, my friend, ere you address it,
Boil it down.

Skim it well—then skim the skimmings—
Boil it down.
When you're sure 'twould be a sin to
Cut another sentence in two,
Send it in, and we'll begin to—
Boil it down.

Graduate students sometimes gain the impression that this matter of writing is very inconsistent. In writing up a thesis full data and minute description are required, but the same material prepared for publication is greatly reduced.

It frequently happens that publication of results or expression of ideas in one field stimulates fruitful thought and activity in another. Darwin's work attracted the attention of an obscure person who was a teacher of physical science not even trained in biology. He grew peas in a garden and his work

became the foundation for modern plant and animal breeding. Mendel's contribution was unnoticed until sixteen years after his death. And during that same period Darwin's book on "Variation of Animals and Plants Under Domestication" just available in America was read by a boy in New England—the nineteen-year-old son of a farmer and brickmaker. According to his own statement this boy was greatly influenced by Darwin's book, and he began cultivating a power of observation that became truly remarkable. Luther Burbank lacked scientific training but he was a master at seeing. What great results can grow from small beginnings! Research, experiment, experience, observation, trial, and error—all are useful in contributing to the total of human knowledge.

Arthur Compton studies cosmic rays, Stanley isolates a high-molecular weight protein virus, Lawrence builds a cyclotron and tags atoms of calcium, phosphorus or nitrogen, Urey finds a new element, heavy hydrogen, and Roger Adams makes derivatives of chaulmoogric acid in an effort to cure leprosy. All of these men have contributed greatly to recent progress in research; two have been awarded Nobel prizes; all have spoken on this campus and we have had occasion to see that they are much like ordinary folks in most respects, but the point I wish to emphasize is that each started his work somewhere not many years ago, as a graduate student with a modest problem.

Finally it might be well to remember that progress has been and is being made by individuals without even the advantages of university training. So far as I am aware no university has come forward to claim credit for having developed the creative spirit in two well-known characters I have already mentioned. Thomas Edison and Luther Burbank seem to have caught something of the research spirit. Out in Delphos, Ohio, lives a draftsman and farmer who is still less than forty years old. In *Science* for January 27, 1939, may be found a brief account of the discovery in the northwestern sky of this year's first comet by Leslie C. Peltier, an amateur astronomer. Prying further into the life of this man one finds that he makes a living by farming and working for the Delphos Bending Company. But from 1925 to 1936 he was the *original* discoverer of six comets and an independent discoverer of seven others. In 1933 he was the discoverer of one of those interesting stellar events known as a nova or bursting star. He has accomplished these discoveries as a side line, working with only a six-inch telescope. He lives on R. F. D. 2, Delphos, Ohio.

In view of the accomplishment of these men, and those whom I mentioned earlier, and of still others, hundreds of whom might be mentioned, I would be disposed to say that research is still an open field with opportunity for all. The great Newton paid a fine compliment to his predecessors when he said that if he saw a little farther than others it was because he stood on giant shoulders, and we might add that each research worker, no matter how small his contribution, is helping to provide the shoulders on which the future investigator will stand, and from which he will peer out into still greater depths of truth.

"SCIENCE IN PROGRESS"

TEN RECOGNIZED LEADERS IN THE PHYSICAL AND BIOLOGICAL SCIENCES HERE DESCRIBE THE METHODS EMPLOYED AND THE RESULTS OBTAINED FROM BASICALLY IMPORTANT RESEARCHES WHICH HAVE RECENTLY ENGAGED THEIR ATTENTION. PARTICULAR ATTENTION IS GIVEN TO THE RELATIONSHIPS BETWEEN THE NEWLY ACQUIRED KNOWLEDGE AND THAT PREVIOUSLY EXISTING. THE LAST FEW YEARS HAVE BEEN MARKED BY UNUSUALLY IMPORTANT ADVANCES IN VARIOUS SCIENTIFIC FIELDS, BUT COMPARATIVELY LITTLE INFORMATION HAS BEEN AVAILABLE RELATIVE TO THESE NEWLY PLACED MILESTONES EXCEPT TO THE ACTIVE WORKERS THEMSELVES. THE DISCOVERIES ARE WELL-ESTABLISHED AND OF SUCH BASIC IMPORTANCE AS TO MAKE IT ESSENTIAL TO HAVE THE INFORMATION ACCESSIBLE TO ALL WHO ARE INTERESTED. THEREFORE, THIS VOLUME BASED UPON THE NATIONAL SIGMA XI LECTURES DELIVERED IN 1937-38 HAS SPECIAL SIGNIFICANCE, SINCE NO OTHER PUBLICATION HAS HAD ACCESS TO THIS MATERIAL. THE BOOK HAS NOT BEEN WRITTEN DOWN TO A POPULAR LEVEL IN AN ENDEAVOR TO ATTRACT THOSE WHO DO NOT HAVE A GENERAL KNOWLEDGE OF MODERN SCIENTIFIC ENDEAVOR, BUT NEVERTHELESS, WHILE MAINTAINING A HIGH DEGREE OF SCHOLARSHIP, THE CHAPTERS ARE INTERESTINGLY WRITTEN AND PROFUSELY ILLUSTRATED WITH STRIKING AND EXTRAORDINARILY VALUABLE PHOTOGRAPHS. HERE ARE THE "MEN AND MACHINES" WHO HAVE MADE IMPORTANT ADVANCES INTO UNMAPPED AREAS, WHO ARE IN THE FOREFRONT OF SCIENTIFIC RESEARCH TODAY.

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THE PRICE OF THIS VALUABLE ADDITION TO MODERN SCIENTIFIC LITERATURE IS $4. ALL PROFITS ACCRUING FROM ITS SALE ARE ADDED TO THE SOCIETY'S RESEARCH FUND. ORDERS SHOULD BE SENT TO THE NATIONAL SECRETARY.

SIGMA XI LECTURE SERIES FOR 1940

Lecturers, lectures, and available dates of the third series of Sigma Xi lectures are announced by the Committee on Lectures as follows:

Lecturer: Professor F. W. Went.
Topic: The Regulation of Plant Growth.
Available Dates: Last two weeks in January.

Professor Went is Professor of Plant Physiology at the California Institute of Technology. He came to the Institute in 1933 from the Botanical Gardens of Buitzenorg, Java, where he had been Director of the Foreigners Laboratory. His research work has been done in plant hormones, plant growth, phototropism, root formation, polarity, the water relation of plants, ecology of epiphytes.

Lecturer: Professor J. F. Fulton, M.D.
Topic: The Functions of the Frontal Lobe; an Experimental Analysis in Monkeys, Chimpanzees and Man.
Available Dates: First two weeks in February.

Doctor Fulton is Sterling Professor of Physiology, in the School of Medicine of Yale University. His experience includes association with Magdalen College of Oxford University, and with the Peter Bent Brigham Hospital in Boston. His investigations cover the blood pigments of invertebrates, especially of Ascidians, the nature and significance of the electrical response of contractile tissues, the reflex coordination of movement and posture, and the comparative physiology of the primate brain.

Lecturer: Professor J. W. Beams.
Topic: High Speed Centrifuging.
Available Dates: First two weeks in March.

Professor Beams is Professor of Physics at the University of Virginia. His researches include the measurement of very short time intervals, the Kerr effect, electrical discharges, and ultra-centrifuges.

Lecturer: Professor Douglas Johnson.
Topic: Mysterious Craters of the Carolina Coast.
Available Dates: Last two weeks of March.

Professor Johnson is Professor of Physiography at Columbia University and Executive Officer of the Department of Geology and Mineralogy. He has filled national and international positions of importance. He has been connected with the United States Geological Survey, and has been geological adviser of the United States Department of State. He was Consulting Physiographer for the Canadian Government in the Labrador boundary dispute. He has been awarded medals by many societies in this country and Europe. His researches include the physiography of lands, shore-line physiography and military geography.

Lecturer: Dr. D. A. MacInnes.
Topic: The Motions of Ions and Proteins in Electric Fields.
Available Dates: Last two weeks of April.

Doctor MacInnes is associated with the Rockefeller Institute for Medical Research in New York City, and was formerly Associate Professor of Physical Chemistry at the Massachusetts Institute of Technology. His research work has been done in the field of solutions of electrolytes and of electrochemistry.

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All insignia of the Society are available only through the office of the National Secretary. They are made in various styles and sizes, and in white and yellow gold. Orders for these insignia are issued through chapter secretaries, and must be *prepaid*. Information about styles and prices may be obtained from chapter secretaries or the National Secretary.

DIPLOMAS FOR MEMBERS AND ASSOCIATES

These diplomas are available in any quantity at 10 cents each. Diplomas can be engraved with the name of the individual and of the chapter and the date of initiation at 25 cents each. Orders should be sent to the National Secretary, should specify whether for members or associates, and should be accompanied by check.

INDEX CARDS

Index cards for newly elected members and associates are available *gratis* upon requisition from chapter secretaries to the National Secretary. These cards should be made out in duplicate, one set being retained for chapter files and one set being sent to the National Secretary for filing in the permanent records of the national organization.

NATIONAL CONSTITUTION

Printed copies of the National Constitution and History of the Society are available at 5 cents each from the National Secretary.

CHANGES OF ADDRESSES

Chapter secretaries are asked to send to the National Secretary in October of each year changes in their enrollment lists as follows: 1. Names and addresses to be deleted from the previous list; 2. Names and addresses to be added to previous list; 3. Changes of addresses of those on previous list who may have moved to a new address since the list was submitted.

SIGMA XI STATIONERY

Stationery in the official color of the Society is now available for all chapters and clubs at $5 per 500 sheets and $5 per 500 envelopes. The letter sheets bear the Society's seal embossed in white but no printing. The envelopes are the official square envelopes used by the national officers. Printed heading on the sheets and printed corner cards on the envelopes can be provided at cost, when so desired.

EDWARD ELLERY,
National Secretary, Sigma Xi,
Union College,
Schenectady, N. Y.